Wireless communication using Implantable Antennas

A Synopsis submission in partial fulfillment of the requirements for the Degree of

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in
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Introduction

Wireless communication is receiving most interest nowadays in biomedical field. In biomedical field wireless transmitters and receivers are very much helpful for experts to find exact data of the body of patient in same way it is easy to use and comfortable for patient. The variety of medical devices is being used into human body for sensing and monitoring and wireless implanted communication is required for adequate working of these devices [1].

Many devices are coming into market for medical monitoring and many more to come in future. Medical implant communication services (MICS) are used with frequency band 402-405 Mhz. In biotelemetry there is implanted device inside the body of patient and receiver is there at monitoring place both are connected via wireless link as shown in fig-1 [2]. This wireless biotelemetry allows doctors to establish a reliable and high speed link for health monitoring. High speed data transfer, images and video transfer is not possible in MICS band, but there is another band as UWB (IEEE802.15.TG6) which provides 3.1 to 10.6 Ghz range [6]. This band is sufficient for high speed data transfer and video transfer [6].

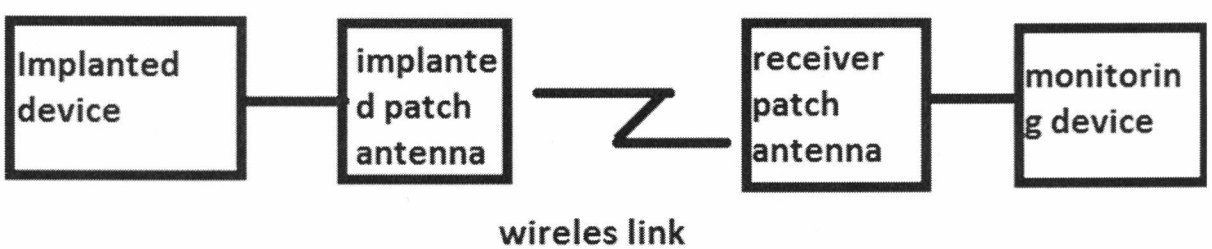

Fig 1: Block diagram of wireless communication using implantable antenna

Hence first requirement of wireless biotelemetry is an antenna which is body compatible and can send high speed data. Normal patch antennas cannot be used inside the body due to large size and no suitability within the body. Miniaturized and biocompatible patch antennas can be used inside the body for making a wireless communication link in between transmitter and receiver[11]. Implanted antennas are surrounded by lossy medium with respective to frequency so antenna performance could be vary with tissue parameters .Properties of human body should be known for which implantable antenna is to be designed. constructing a reliable wireless link human body electrical properties of body are of deep interest.

Motivation

Recent development in implantable devices is showing keen interest in implantable patch antenna so that biotelemetry would be wireless, high speed and secured. So biocompatible and high speed supporting patch antennas designing is a challenge in wireless biotelemetry. Some implantable patch antennas were designed earlier but they are less biocompatible, low bandwidth, less efficiency and of bulky size. So there is requirement of implantable patch antenna which would be best suited for physicians and patients.

Literature review

- Z. Tang, B. Smith, J. H. Schild, and P. H. Peckham, "Data Transmission from an Implantable Biotelemetry by Load-Shift Keying Using Circuit Configuration Modulator," *IEEE Transactions on Biomedical Engineering*, 42, 5, May 1995, pp. 524-528.
- **It provided the first spark of implantable biotelemetry in 1995.**

- **Design of implantable GPS antenna was presented by**

- Y. Zhou, C. C. Chen, J. L. Volakis, "Dual Band Proximity Fed Stacked Patch Antenna for Tri-Band GPS Applications," *IEEE Transactions on Antennas and Propagation*, AP-55, 1,January 2007, pp. 220-223.

- **It provided an idea of mimicking gels for testing in equivalent model.**

- T. Karacolak, A. Z. Hood, and E. Topsakal, "Design of a Dual-Band Implantable Antenna and Development of Skin Mimicking Gels for Continuous Glucose Monitoring," *IEEE Transactions on Microwave Theory and Techniques*, 56, 4,April 2008, pp. 1001-1008.

- **After announcement of MICS band planar antenna design**

- N. Cho, T. Roh, J. Bae, and H.-J. Yoo, "A planar MICS band antenna combined with a body channel communication electrode for body sensor network," IEEE Trans. Microw. Theory Tech., vol. 57, no. 10, pp. 2515–2522, Oct. 2009

- **Some different designs are suggested as -**

- Y.-S. Wang and S.-J. Chung, "A short open-end slot antenna with equivalent circuit analysis," IEEE Trans. Antennas Propag., vol. 58, no. 5, pp. 1771–1775, May 2010.

- A. Kiourti, M. Christopoulou, and K.S. Nikita, "Performance of a novel miniature antenna implanted in the human head for wireless biotelemetry," in Proc. IEEE Int. Symp. Antennas Propag., Spokane, Washington, 2011, pp. 392–395.

- J. Ha, K. Kwon, and J. Choi, "Compact zeroth-order resonance antenna for implantable biomedical service applications," Electron. Lett., vol. 47, no. 23, pp. 1267–1269, Nov. 2011

- **Hybrid patch design**

- M.-C. Tang, S. Xiao, Y.-Y. Bai, T. Deng, C. Liu, Y.-P. Shang, C. Wei, and B.-Z. Wang, "Design of hybrid patch/slot antenna operating in induced

"TM120 mode"," IEEE Trans. Antennas Propag., vol. 60, no. 5, pp. 2157–2165, May. 2012

- **Miniaturization of Scalp implanted antenna in MICS band**
- A. Kiourti and K. S. Nikita, "Miniature scalp-implantable antennas for telemetry in the MICS and ISM bands: Design, safety considerations and link budget analysis," IEEE Trans. Antennas Propag., vol. 60, no. 8, pp. 3568–3575, Aug. 2012.

Objectives and Scope

Human body is conductive in nature so antenna can be short circuited that's why biocompatible materials are used in designing and fabrication of these antennas. Commonly used biocompatible materials are Teflon and ceramic alumina.

(λ /4) and (λ /2) antennas are not suitable for implanted antennas because antenna large size is also a problem in biotelemetry. so miniaturization is required to reduce the size of implanted antenna. Some strategies are there for miniaturization as using high permittivity dielectric, lengthening the current flow path on patch, using shorting pins and patch stacking.

Specific absorption rate is also a limiting criterion for implantable patch antennas. According to IEEE C95.1-1999 standard allowable SAR range is 1.6W/Kg .There is strict limit for effective radiated power -16 dbm in implanted devices. Low power consumption is also a parameter for implantable patch antenna. So these are some limitations and scope under which implantable patch antenna has to be designed and fabricated.

Description of research work

Antenna designing under the conditions explained in above section is required. This is to be tested inside human body, so it will be simulated in an environment which is similar to human body. There are phantoms available for testing the parameters of implanted antenna. It will not be simulated in normal air box as in normal patch antenna. So there is requirement of a phantom model with the body

parameters [13]. Canonical shaped phantoms are chosen for testing of implantable patch antenna. Some parameters for canonical shaped phantom are as follows:

Tissue(s)	**Shape(volume [mm3])**	**State**	**Ingredients**	**[MHz] F**	εr	Σ
Skin	cubic (100 × 100 × 100)	Liquid	deionized water, sugar, salt,	402	46.7	0.69
muscles	rectangular	Liquid	water sugar, salt, TX-151 powder,	402	48.9	0.71
Skin Fat Muscle	rectangular (40 × 80 × 160)	(multilayer) Gel	deionized water, sugar deionized water, salt, vegetable oil, fl our deionized water, sugar, salt	868	38.7 4.9 53.0	0.77 0.04 0.92

In above model implantable antenna is simulated sandwiched between these layers. These layers are playing role of skin, muscle and fat with similar electrical model of all these. In electrical model all these layers are treated as attacked structure of different dielectrics. So the implanted patch antenna is simulated in this structure. Model for simulation of patch antenna is shown in below diagram.

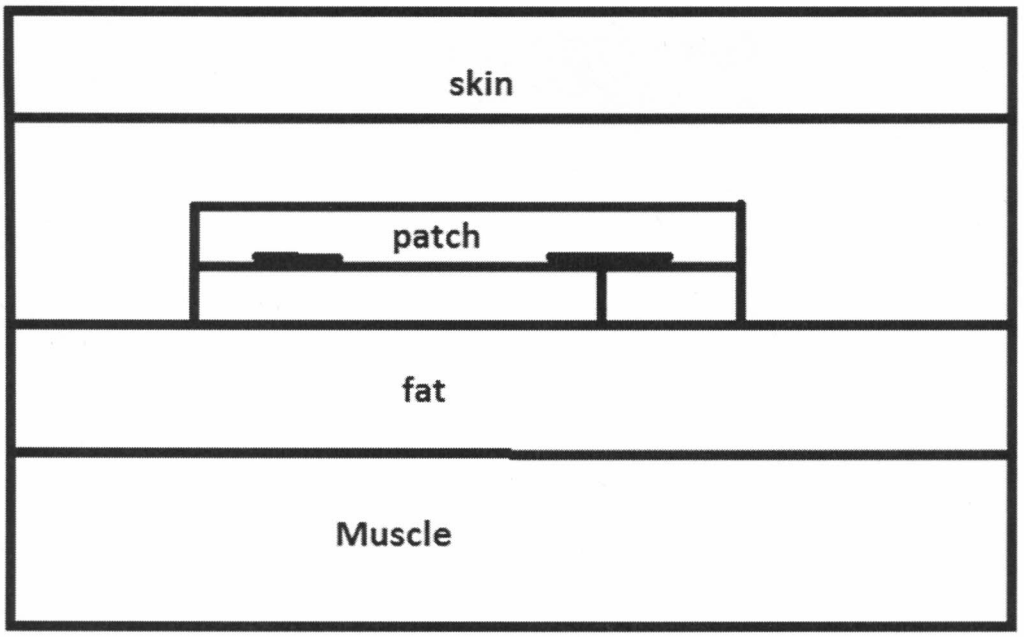

Fig-2: Proposed Stacked model of implanted patch antenna [7]

Numerical method and software

Equivalent model of implanted patch antenna can be simplified by spherical Dyadic Green's function. The electromagnetic solver used here is finite element method in Ansoft HFSS simulator. This simulator breaks the structure in small finite element and then forms electromagnetic equations for solving it.

Prototype Fabrication

Proposed biocompatible material is rogers 3210 ($\varepsilon r = 10.2$, $\tan\delta = 0.003$).This material is favorable for human body as well as for patch. Prototype fabrication of implantable antennas meets all classical difficulties of miniature antennas. For example, additional glue layers used to affix all components together strongly affect antenna performance, by shifting the antenna's resonance frequency and degrading its matching characteristics

Testing inside the phantoms

The fabricated prototype is proposed to immersed inside a tissue phantom (i.e., a container filled with a liquid or gel material that mimics the electrical properties of biological tissue), and measured. For validation purposes, the same scenario as that of the numerical simulations has to be considered.

Canonically-shaped phantoms are proposed to use for testing of implantable patch antennas. In this case, the main challenge lies in the formulation and characterization of tissue-emulating materials [7]. Recipes proposed phantom mainly included demonized water, sugar, and salt.

Summary of work

Proposed Body implanted patch antenna can be simulated and fabricated as above description but having several limitations, which are limiting the performance of patch antennas. Main challenges are that antenna should be easily accepted by physicians and patients showing all acceptable electrical parameters. If all parameters are simulated correct then fabrication of antenna in phantom showing similar results as in simulation will be a great challenge.

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